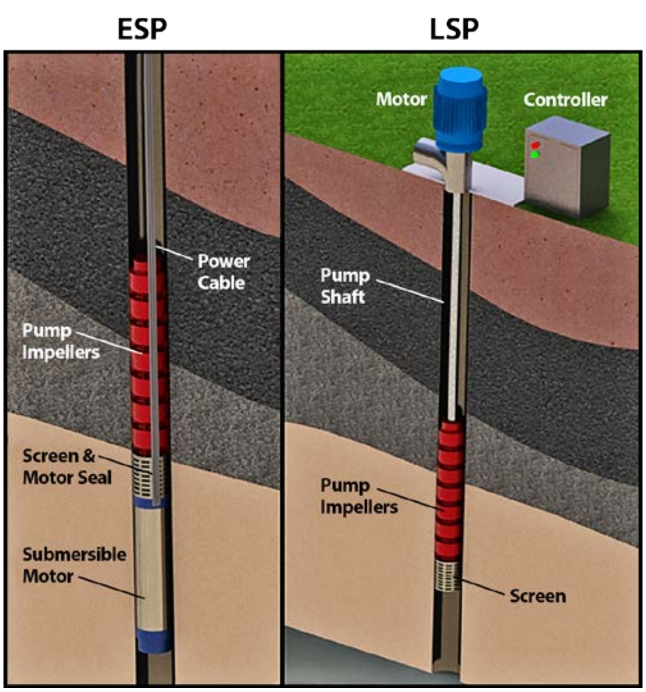
Electronic Submersible Pump (ESP) Technology and Limitations with Respect to Geothermal Systems

The possibilities and challenges with ESPs for geothermal electricity production

ESP: A Solution to Artificial Lift

NREL analyzed current ESP technology to understand the capabilities and limitations with respect to geothermal electricity production. Current geothermal technology has limitations that hinder the expansion of utility-scale power generation. Developers note that one limitation is artificial lift (Jenne 2014). With the exception of a few geothermal fields, line shaft pumps (LSPs) dominate the production of artificial lift.

The motor in an LSP assembly is above ground, requiring the power shaft to extend to the depth of the pump. This configuration puts a high strain on the power shaft and limits LSPs to approximately 2,000 feet (Culver and Fafferty 1998). As enhanced geothermal systems (EGS) reach greater depths, LSPs are at greater risk of failure due to the high angle of twist as a result of both torque and shaft length. Shaft stress is also increased at greater depths from lateral movement at startup due to the higher head demand. Depth aside, LSPs are incapable of operating in horizontal wells or other highly deviated wells. LSP shaft bearings also require lubrication which can cause well contamination (Jenne 2014b). ESPs, on the other hand, have all mechanical components downhole, leaving only the controller above ground. The technology can also function in angled or horizontal wells. For this reason, ESP technology has been widely adopted for oil extraction. ESPs consist of five major components (Baillie 2002):



- Power supply/controller
- Power cable
- Pump
- Seal/bearing package
- Electric motor.

However, the operating conditions in an oil field vary significantly from a geothermal system. One of the most notable differences with respect to artificial lift is that geothermal systems operate at significantly higher flow rates, and with potential advancements from EGS, at even greater depths. The large flow rates associated with geothermal systems require horsepower ratings which can exceed 1,000 horsepower (hp) per well. While oil wells can be at greater depths, the lower flow rates allow for lower-hp motors. Geothermal systems also operate in a variety of harsh conditions including, but not limited to: high temperature, high salinity, high concentrations of total dissolved solids (TDS), total suspended solids (TSS), and non-condensable gases.

Challenge: Operating Conditions

Extensive work has been done to increase the operating temperature and the power capacity for all components within the ESP system, as well as the ability to operate in harsh environments.

Steam assisted gravity drain (SAGD) oil recovery has paved the way for high-temperature ESPs. The current market includes motors that are capable of operating up to 482°F (250°C). While these motors far exceed the temperatures of typical hydrothermal systems, they are limited to approximately 250 hp (Schlumberger 2013).

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On the other end of the spectrum, the current market includes motors that are rated up 1,500 hp (Wood Group 2004), and ratings up to 2,800 hp can be achieved with multiple motors in series (Baker Hughes 2011). However, at these ratings, motors are typically limited to below 325°F (163°C). Some of this temperature de-rating is due to material selection, but high-hp motors inherently put out more heat, and therefore high-temperature motors would still require a de-rating if simply scaled up (Burleigh 2013).

Geothermal plant located at Stillwater, Nevada.

Photo from Sierra Pacific, NREL 07209

Regardless of temperature or power rating, one of the biggest concerns with the current ESP marketplace is the operational life at these extremes. Current ESPs have a typical operational life of only two to three years, and as temperature increases, life expectancy is further reduced (Vandevier 2010).

Some new R&D efforts are looking at new design and material configurations to push high-temperature and high-hp boundaries even higher. Novel designs such as hollow core motors (Turnquist 2013) and advanced polymer compounds (Hooker 2011) are being considered to reduce the failure rates and increase performance.

Technology and R&D Opportunities

The ESP research to date has focused on individual problems for oil wells—not an integrated, comprehensive solution so that an ESP system can operate reliably for geothermal electricity production. Additionally, testing for new ESP designs is expensive and a large barrier for new participants.

The ESP market is dominated by a small number of OEMs that have the ability to perform accelerated testing at full scale. Large OEMs that have invested in multimillion-dollar facilities have the ability to test ESPs at extreme conditions (Vandevier and Gould 2009). Companies with less access to capital find it difficult to compete without access to full-scale testing (required by some investors). And as the need to test more extreme temperature, power rating, and environmental extremes continues, the need for advancements in ESP testing facilities could grow.

One solution could be a third-party testing facility that can replicate the harsh conditions for geothermal ESP applications. Although a large investment, access to such a testing facility could potentially reduce entry barriers by allowing more researchers to solve and test ESP design challenges for geothermal applications. This could be a critical component for geothermal industry growth.

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